Statistical Prediction Models for Network Traffic Performance

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Outline

- Goal
- Data
- Models
- Results

Goal

Statistical Prediction Model

- By analyzing
  - network traffic patterns and variation with the network conditions
  - based on two types of historical network measurement data
- To develop
  - performance prediction models for high-bandwidth networks
  - forecast the future network usage for a given time window and with a given probabilistic error requirement

Data and Modeling

- **SNMP Data**
  - **Single time series**
  - **With even collecting frequency**
  - **Develop time series model with Seasonal Adjustment**

System Time	Bytes
1336350930	7899633.733
1336350960	10665164.133
1336350990	13223715.5
1336351020	12133668.13
1336351050	12647888.6

Data and Modeling

- **Netflow Data**
  - **Multivariate data**
  - **Random colleting behavior**
  - **Multiple time series**
  - **Develop Generalized Linear Mixed Model**

Start time	0930.23:59:37.925
End time	0930.23:59:37.925
Source interface	179
Source IP address	xx.xx.xx.xx
Source Port	xxxxx
Destination Interface	175
Destination IP address	xxx.xxx.xxx.xxx
Destination Port	xxxxx
Packets	1
Octets	52

Modeling - Seasonal Adjustment

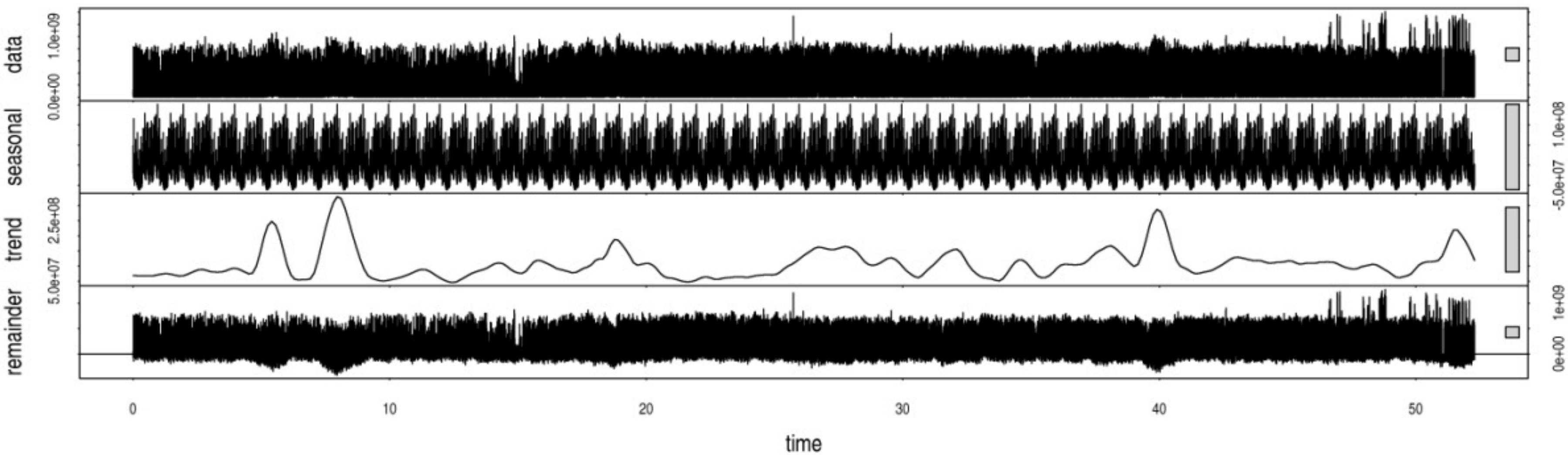
- A time series model with Seasonal Adjustment
- Decompose the SNMP data into three components
  - Seasonal component
  - Trend component
  - Random component.
- Enables an effective analysis in
  - prediction
  - tracing the network traffic and quantifying the variation of the network traffic that flows into multiple outlets

Modeling - Seasonal Adjustment

Y_t	Original series
C_t	Trend component
S_t	Seasonal component
I_t	Irregular component
A_t	Adjusted series (without seasonal component)

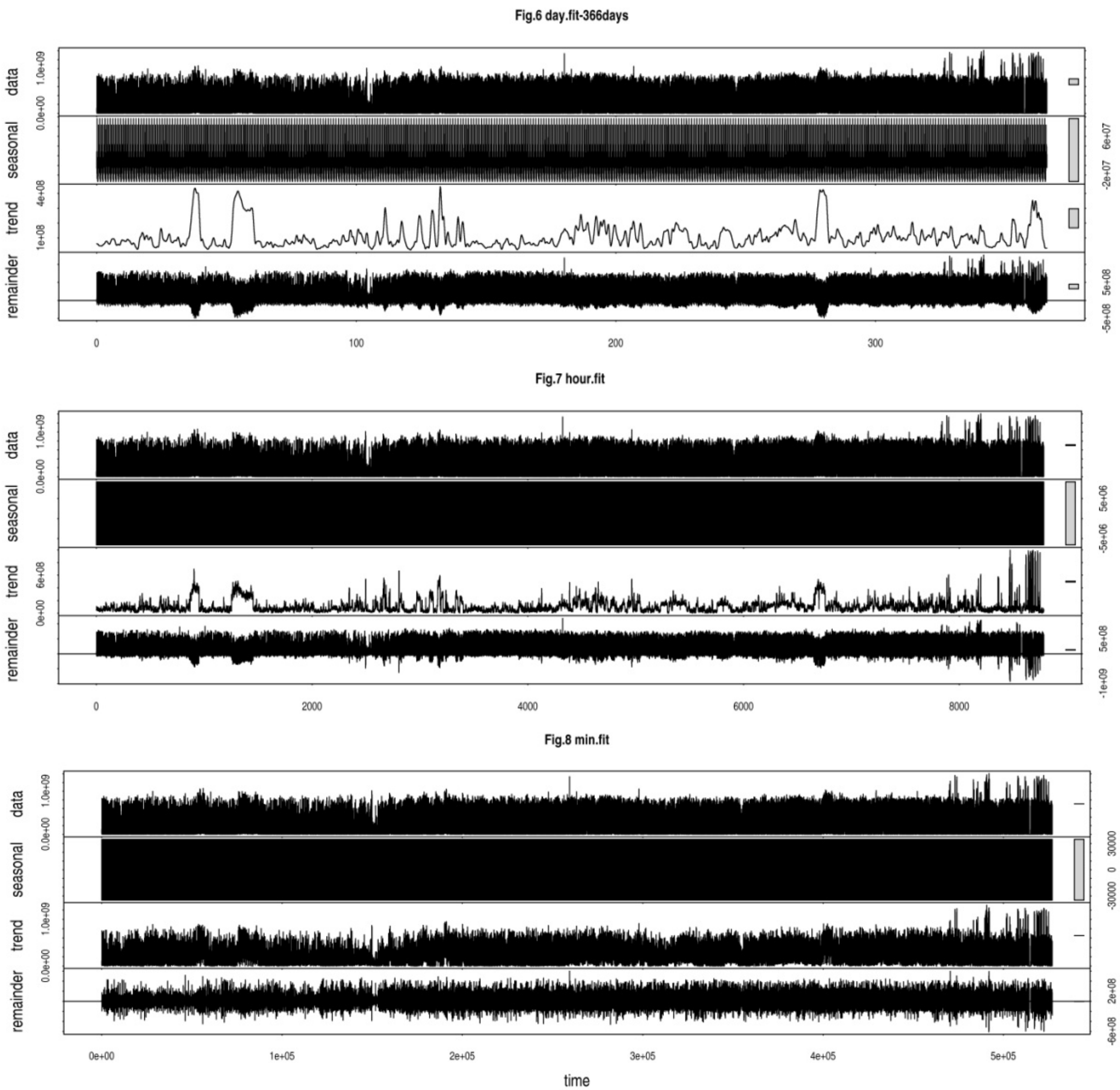
Multiplicative	$Y_t = S_t C_t I_t$	$A_t = C_t I_t$
Additive	$Y_t = S_t + C_t + I_t$	$A_t = C_t + I_t$
Log-Additive	$\mathrm{Ln}(Y_t) = C_t + S_t + I_t$	$A_t = \exp(C_t + I_t)$

Modeling - Seasonal Adjustment



- Seasonal adjustments showing original SNMP data and decomposed components with weekly periodicity at NERSC router

Statistical evaluation of periodicity



- **Seasonal adjustments showing original SNMP data and decomposed components with daily, hourly and minutely periodicity at NERSC router**

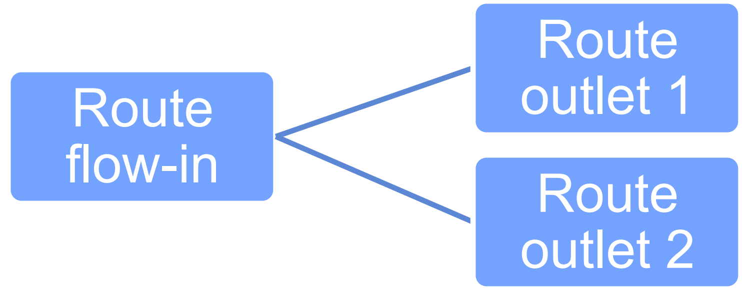
	Seasonal	Trend	Remainder
Weekly	43.2%	44.6%	78.3%
Daily	28.1%	69.1%	53.0%
Hourly	5.7%	88.5%	29.8%
Minute	0.1%	98.5%	6.8%

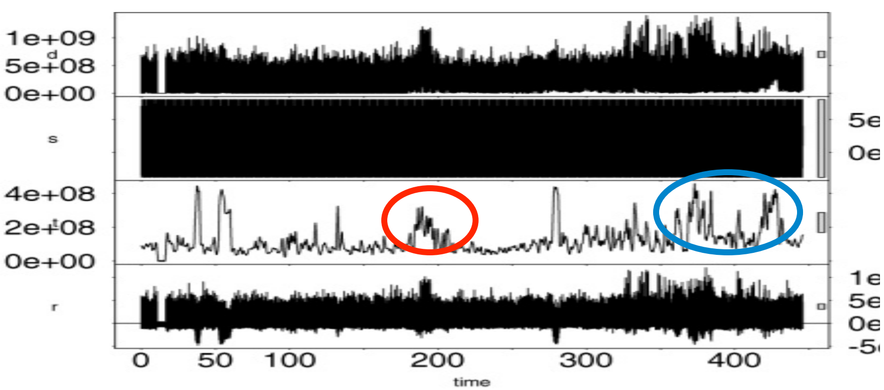
Evaluation of periodicity

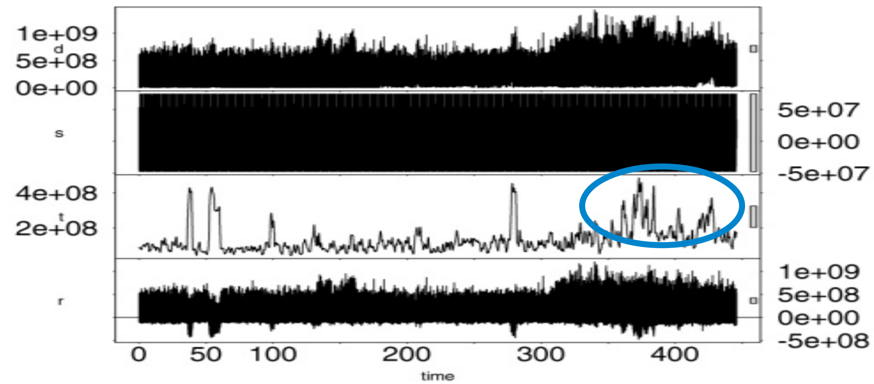
- Identified Seasonality
- Residual Seasonality
- Log transformation

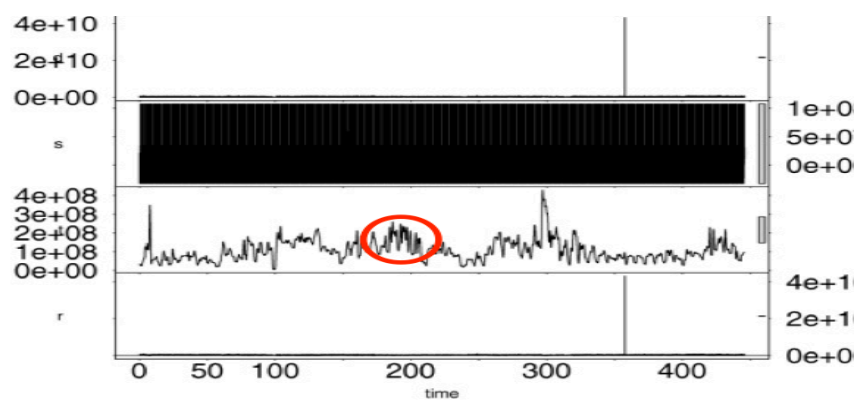
cycle	identified seasonality			residual seasonality			log transformation		
	Yes	no	Yes/total	yes	no	Yes/total	yes	no	Yes/total
Hour	59	119	0.331461	3	175	0.016854	128	50	0.719101
2hour	47	42	0.52809	3	86	0.033708	71	18	0.797753
8hour	6	16	0.272727	0	22	0	19	3	0.863636
10hour	2	15	0.117647	0	17	0	16	1	0.941176
12hour	6	8	0.428571	0	14	0	12	2	0.857143
14hour	1	11	0.083333	0	12	0	11	1	0.916667
20hour	1	7	0.125	0	8	0	7	1	0.875
22hour	0	8	0	0	8	0	7	1	0.875
day	7	0	1	0	7	0	7	0	1
2day	3	0	1	0	3	0	3	0	1
week	1	0	1	0	1	0	1	0	1

Tracing Data Flow

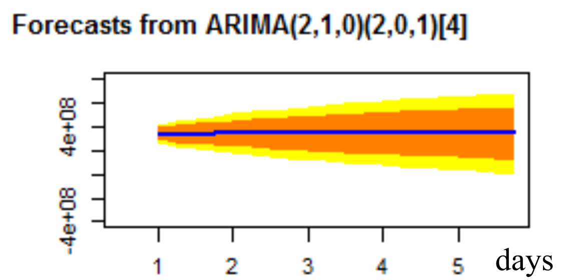


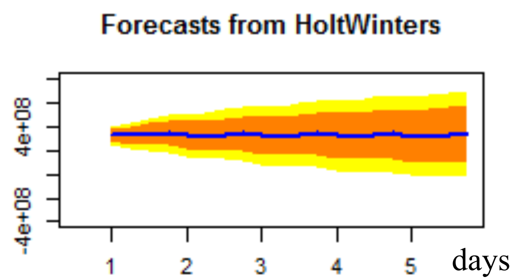


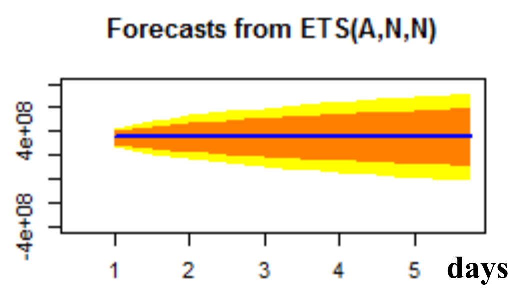


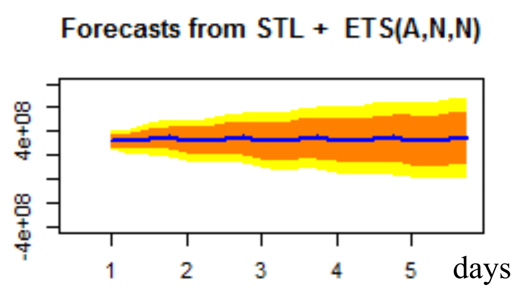


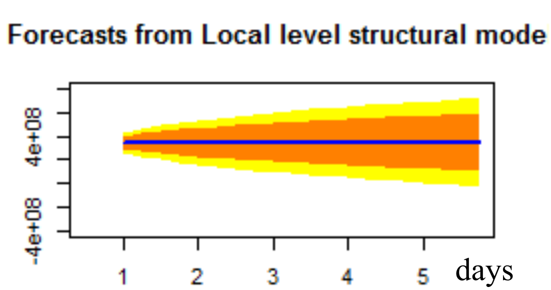
Performance of Prediction

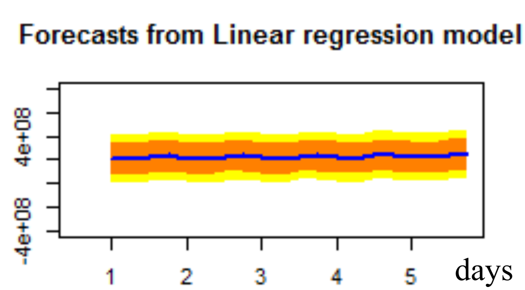










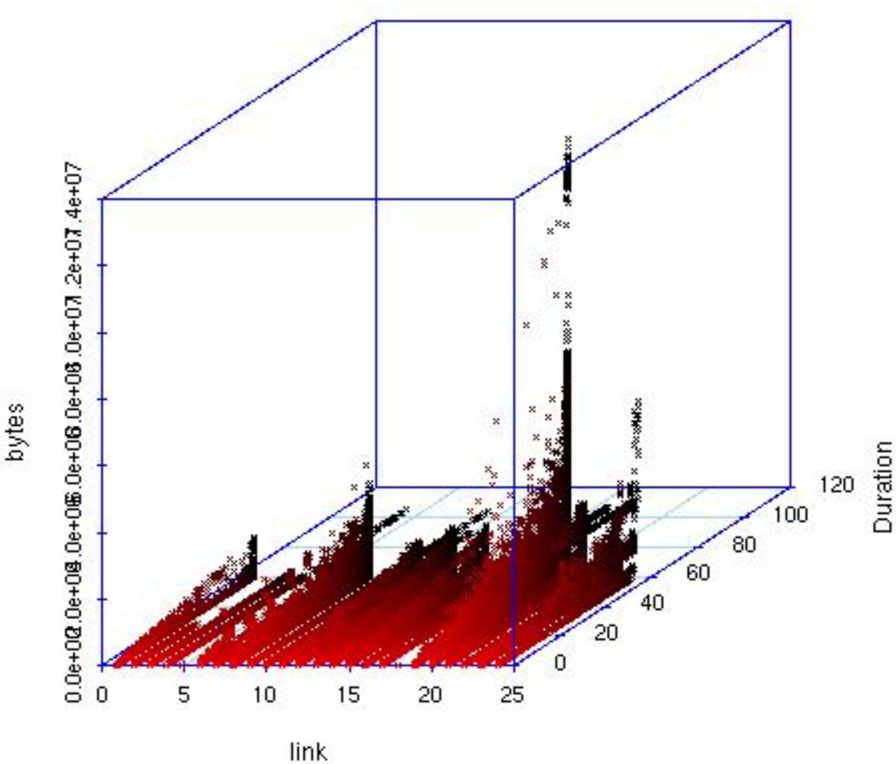


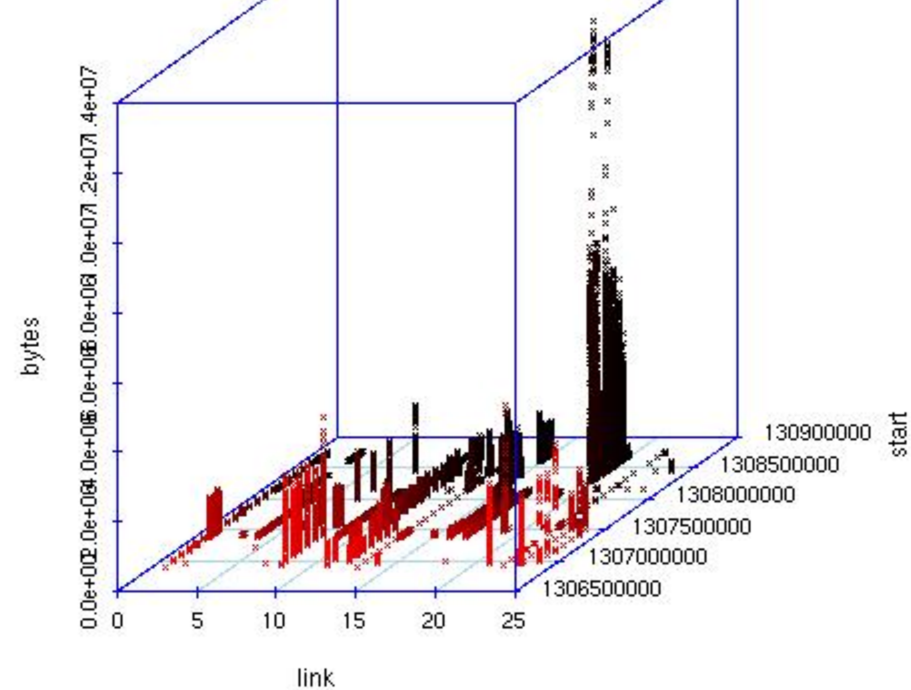
Generalized Linear Mixed Model

$$y = X\beta + Z\alpha + \epsilon$$

- For multivariate data analysis, the behavior of influence from each variable to the prediction is different.
  - Fixed effect: determined influence all the time
  - Random effect: random influence with a certain known distribution
- For multivariate data analysis, the randomness/ uncertainty comes from different sources
  - Error term: the universal variance caused by randomness
  - Random effect: the variance nested within the diversity in the network conditions

Netflow Data





3D Plots suggest random effects.

GLMM on Octets

- **How bytes is related to the timestamps and paths it take.**

$$y_{ij} = X\beta_j + Z\alpha_i + \epsilon_{ij} \quad i = 1, \ldots, m, j = 1, \ldots, l$$

where m is the number of distinct routes with direction

l is the number of unique timestamps

y_{ij} is the observational bytes

$X\beta_j$ is the mean of Octets for the jth observational time

$Z\alpha_i$ is a random effect associated with the ith route

ϵ_{ij} is an error term.

GLMM on Duration

- **How long to expect based on the size of the flow, start time of transfer and selected routes**

$$y_{ij} = X\beta_j + Z\alpha_i + \epsilon_{ij} \quad i = 1, \dots, m, j = 1, \dots, l$$

where m is the number of distinct routes with direction

l is the number of unique timestamps

y_{ij} is the observational duration

$X\beta_j$ is the mean of Duration for the certain size of flow at jth observation time

$Z\alpha_i$ is a random effect associated with the ith route

ϵ_{ij} is an error term.

GLMM on Octets

$$y_{ij} = X\beta_j + Z\alpha_i + \epsilon_{ij}$$

Octets ~ SrcP + DstIPaddress + Pkts

+ (1 | SrcIPaddress) + (Pkts |SrcIPaddress)

- **Fixed Effects: β_j Coefficient**

Intercept	54938.5706
SrcP (SourcePort)	-1.8182
DstIPaddress (Destination IP address)	4398.0490
Pkts(Packets)	3270.7419

- **Random Effects: α_i Variance**

SrcIPaddress (variance)	3.8210e+08
Pkts (variance)	1.0663e+07

GLMM on Duration

$$y_{ij} = X\beta_j + Z\alpha_i + \epsilon_{ij}$$

Duration ~ DstP + Pkts + start.r

+ (1 | SrcIPaddress) + (Pkts |SrcIPaddress)

- **Fixed Effects: β_j Coefficients**

Intercept	1.018e+02
DstP(Destination Port)	-2.252e-04
DstIPaddress (Destionation IP address)	4.152e-01
start.r	-7.597e-06

- **Random Effects: α_i Variance**

SrcIPaddress (variance)	123.39220
Pkts (variance)	0.17914

Conclusion

- Statistical approach to the prediction models for network traffic performance based on two types of data

- SNMP → Time series model with Seasonal Adjustment
  - Analyzing network traffic patterns
  - By decomposing into seasonal, trend and random components
  - To enable prediction, tracing and quantifying the network traffic
- Netflow → Generalized Linear Mixed Model
  - Analyzing variation with the network conditions
  - By considering fixed effects, random effects and error term
  - To improve accuracy of prediction by involving both universal varaince caused by randomness and variance by changes in the network traffic

More information

- Project web: http://sdm.lbl.gov/apm/
- Contact: kjhu@lbl.gov